



# On-Demand Mobility (ODM) Technical Pathway:

## Enabling Ease of Use and Safety

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# Goals and Benefits

## ODM Safety and Ease of Use

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### Goals

- Improved ease of use and safety
  - Long-term goals: automotive-like training and workload & better-than automotive safety
  - Ease-of-use encompasses initial and recurrent training, preflight & in-flight workload

### Benefits

- Necessary (but not sufficient) for **practical aircraft-based ODM**
- Faster, less risk averse, lower-cost proving ground for new technology and operations **beneficial to transport aircraft**
- Technologies that help address **NTSB's Most-Wanted aviation safety** improvements
  - General aviation loss of control
  - Public helicopter safety
  - Procedural compliance

# What are the Challenges?



## Gulf of Technology, Policy, and Acceptance

**Contemporary,  
Highly Automated  
Aircraft**

**Flying that's as Easy  
(...or Easier) and Safer  
than Driving.**

*Technical  
feasibility*

*Airworthiness  
Certification*

*Training and  
Operational credit*

*Acceptance*

# Presentation Outline: Safety and Ease of Use

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- **Alignment of proposed ODM research with NASA Strategic Thrusts**
- **Performance requirements and current state of the art**
  - How safe is safe enough and is it achievable?
  - How has technology simplified piloting already?
  - Emerging automation technologies
- **“Simplified Vehicle Operations” (SVO), proposed research strategy**
  - Planned evolution & incremental revolution
  - Pilots -> Trained operators -> users
- **Next steps**

# NASA Aeronautics Strategic Thrusts



## Safe, Efficient Growth in Global Operations

- Enable full NextGen and develop technologies to substantially reduce aircraft safety risks



## Innovation in Commercial Supersonic Aircraft

- Achieve a low-boom standard



## Ultra-Efficient Commercial Vehicles

- Pioneer technologies for big leaps in efficiency and environmental performance



## Transition to Low-Carbon Propulsion

- Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology



## Real-Time System-Wide Safety Assurance

- Develop an integrated prototype of a real-time safety monitoring and assurance system



## Assured Autonomy for Aviation Transformation

- Develop high impact aviation autonomy applications





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# NASA Aeronautics Strategic Thrusts: Safety, Ease



**Outcome:** Assured autonomy for aviation transformation

**ODM Contributions:** *Significantly simplified piloting skills and training for manned aircraft* while increasing system safety and capability. (ODM Tech challenge 2)

**Outcome:** Develop technologies to substantially reduce aircraft safety risks.

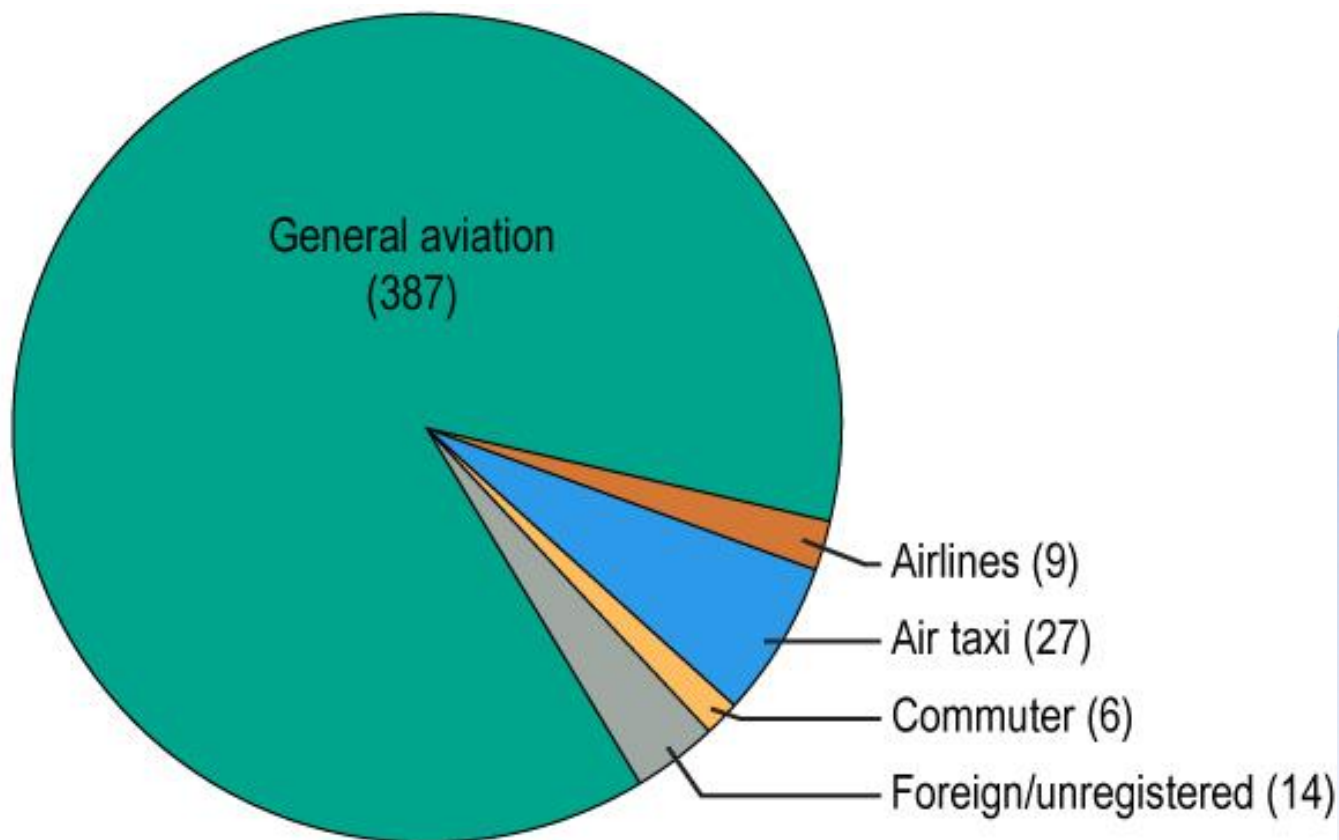
**ODM Contributions:** Increase future small aircraft safety by >10x through combined vehicle, propulsion, and trusted autonomy technologies. (ODM Tech challenge 3)

**ODM provides a technology introduction, validation path for transports**

# NASA Aeronautics Strategic Thrusts: Safety, Ease



2013 Total aviation fatalities: 443,  
420 in general aviation and Part 135 operations  
....95% of total





# Performance: How Safe is Safe Enough?



Mode	Fatalities per hundred million passenger miles	Rate relative to passenger cars
Passenger Cars	0.643	1.0
US Airline Flights	0.0038	167x safer
Commuter Airlines (<10 passengers)	0.102	6.7x safer
General Aviation	7.8 (estimated)	12x less safe

**Challenge:** Bring the safety of all transportation by small aircraft up to the level demonstrated by commuter airlines

# How Has Technology Simplified Piloting?



1990's



2015



+ tablet-based  
electronic flight bag  
for additional  
pre and in-flight  
awareness



# How Has Technology Simplified Piloting?

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➤ **Operationally the change has been tremendous, improving utility, efficiency, average workload, comfort, potential safety, etc.**

- Navigation / position awareness
- Coupled autopilots
- Access to information pre and in-flight
- Electronic flight bags / tablets
- System monitoring, failure detection

➤ **But...**

# How Has Technology Simplified Piloting?



## ➤ ...Becoming and remaining proficient & vigilant is as, if not more, challenging than ever before

- Typically, greater than 500 hours and \$30,000 required to become experienced instrument pilot
- Required knowledge and skills have increased, not decreased
- System and mode complexity has increased
  - Variations between aircraft, software loads
- Pilot expected to detect, troubleshoot & backstop wider range of non-normals
- Average workload is much lower, but peaks remain high, if not higher

# How Has Technology Simplified Piloting ?



➤ ...Realized safety has not significantly changed

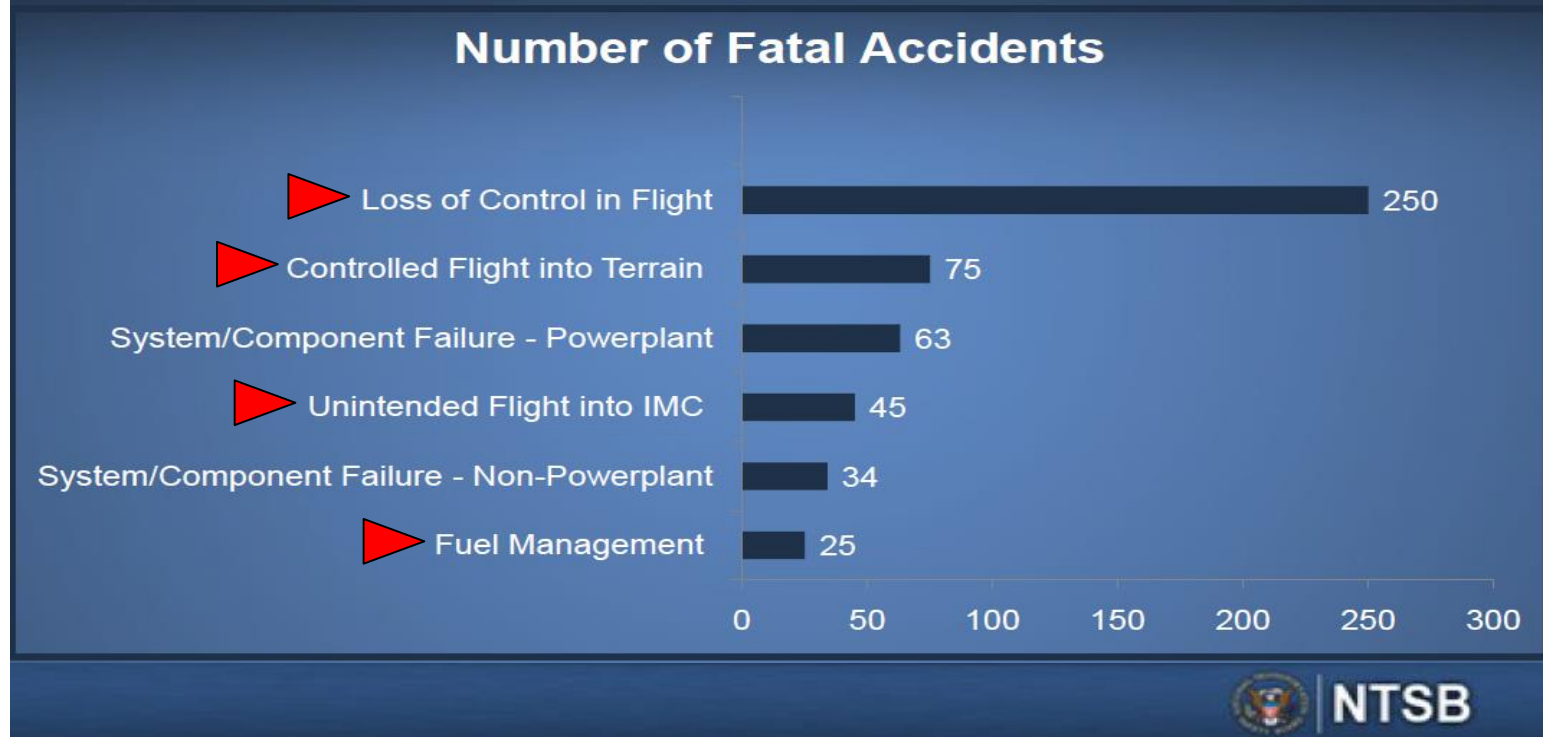


<http://www.nts.gov/investigations/data/Pages/2012%20Aviation%20Accidents%20Summary.aspx>





## Personal Flying Defining Events



- Significant improvement in accident rate by addressing basic errors
- Automotive-level safety achievable by improving relatively deterministic functions
- Age of current fleet contributes to component failure rate



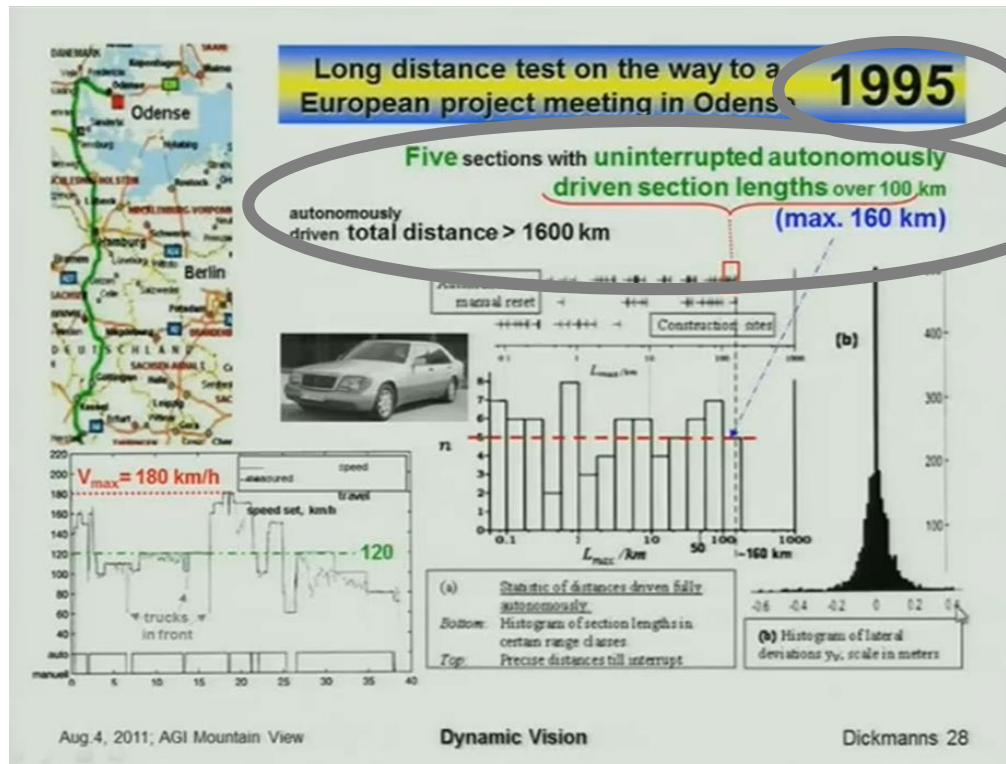
# Are Autonomous Systems a Light on the Horizon?



# Definitely, but We Should Be Realistic



- Costs are plummeting (sensor, computers, data algorithms)
- But:
  - Rate of progress more modest than typically reported...



2003, Honda offers active lane keeping assist (0.2 lateral g)

## LKAS operational conditions

Lane-keeping: Straight roads or curves with a radius of 230m or more  
Vehicle speed: 65-100km/h



### Lane-keeping assist

Provides appropriate steering assistance

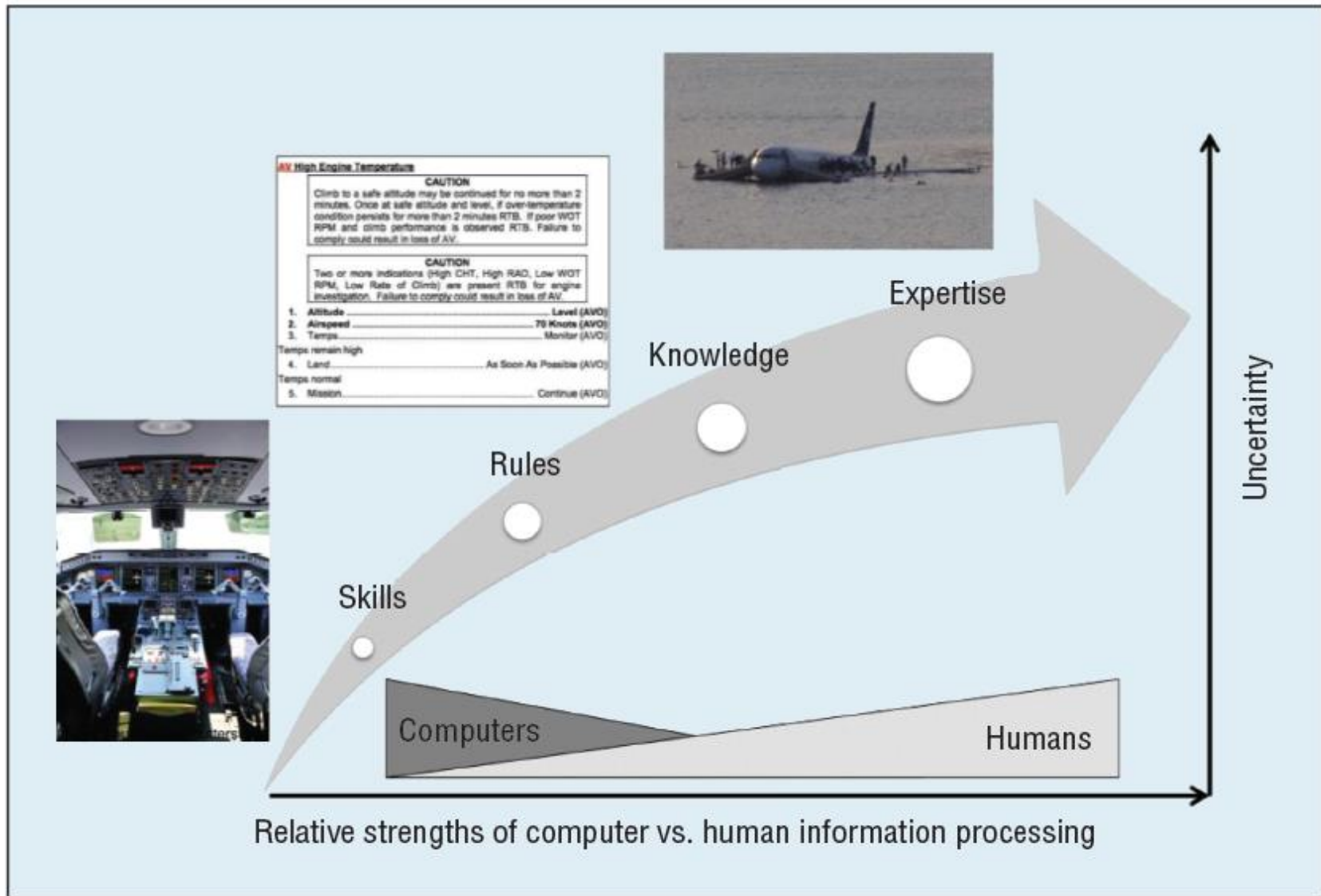


### Lane departure warning

Warns by alarm when departs from lane



# Function Allocation, Humans and Automation



Cummings, 2014; Rasmussen, 1983

# Definitely, but We Should Be Realistic



➤ **Costs are plummeting (sensors, computers, data, connectivity)**

➤ **But:**

- Rate of progress more modest than typically reported...
- Performance in complex, novel situations likely to remain brittle
- Less capable but more reliable systems may have better return on investment
  - It's the corner cases that drive skills, training, monitoring, and costs not the nominal
- Regulators need statistically significant operational histories before approving critical reliance on new technologies & operations without reversion to proven
  - One revolution at a time



# Pathway to Simplified Vehicle Operations (SVO)



## ➤ Transition from expert pilots -> trained operators -> users

- Key steps:

1. Demanding flight-critical, but **deterministic tasks** transitioned from human to **ultra-reliable automation**: sub-system failures must not effect performance
    - Simplified flight control and loss-of-control prevention, navigation, propulsion and systems management
    - Must avoid Air France 447-like scenarios
    - Initially use non-deterministic **autonomy as non-critical decision aids** and in emergency situations (e.g. landing with incapacitated pilot) to gain operational experience, confidence
  2. As trust develops, **transition tasks and responsibilities** from human to autonomy
- Operator training, licensing must evolve with technology, but full credit lags behind

# 3 Epochs of Simplified Vehicle Operation (SVO)

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## ➤ **SVO-1 (2016 – 2026): Key deterministic tasks relegated to automation**

- Technology mitigates pilot as single-point of failure
- Immediately benefits thin-haul commuter ops and latent small aircraft markets
- Expect only incremental airworthiness certification accommodation, but lays foundation for future
- Current FAA training required (e.g. ab initio-to IFR in minimum of 70 hours)
- New pilots capable of comfortable, confident, near-all weather ops.

## ➤ **SVO-2 (2021 – 2036): SPC, Simplified Pilot Certificate**

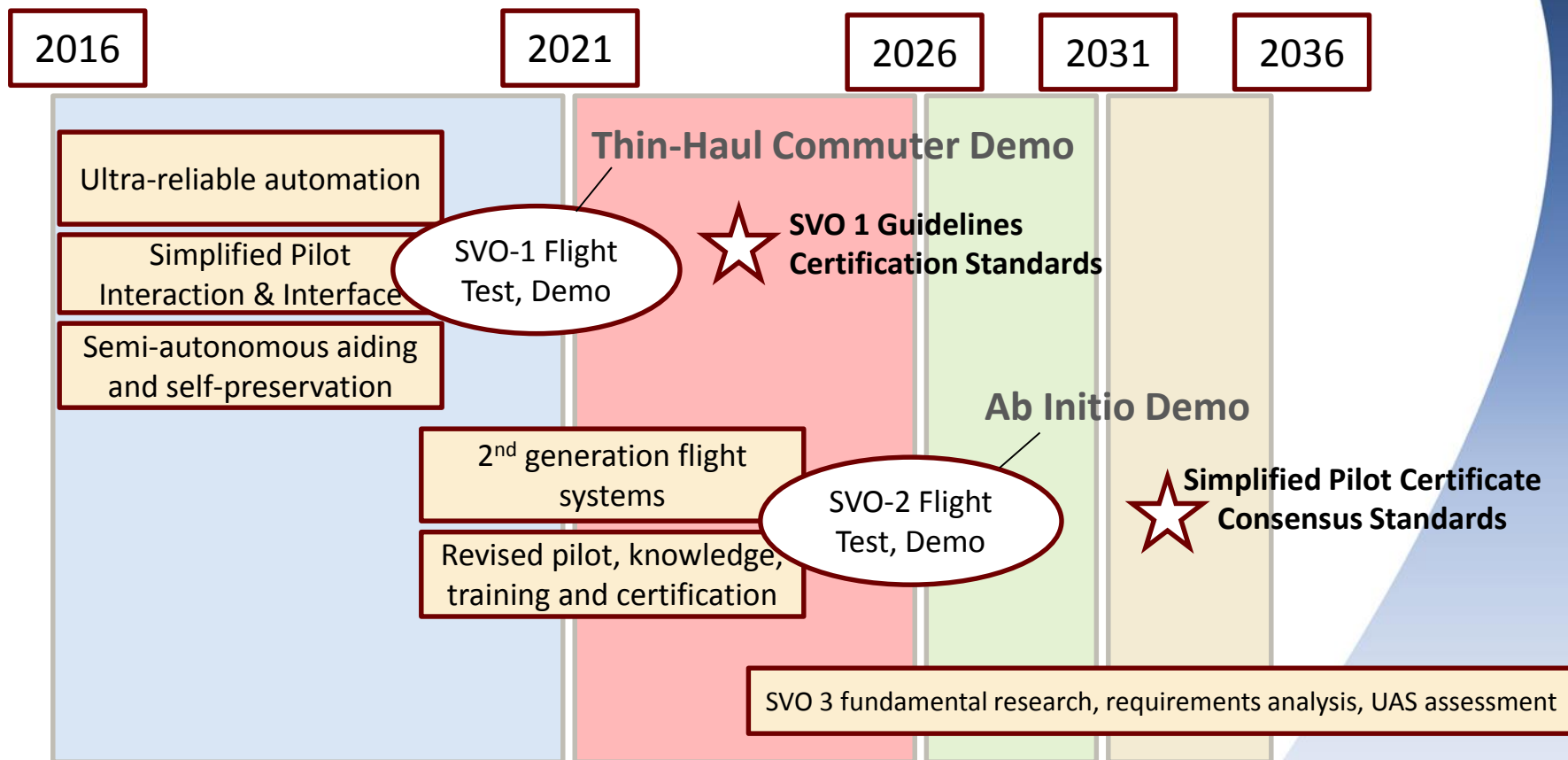
- Simplified training & licensing based on research and operational experience from SVO-1
- New flight system, interfaces, and operation standards that allow updates to training and operational regulations in Part 61, 91, and 135 taking full advantage of technology
- Goal ab initio to near-all weather pilot in <40 hours (similar to driver training)

## ➤ **SVO-3 (2031 - 2051): Autonomous operations**

- Autonomy fully responsible; user involvement in flight is optional



# Simplified Vehicle Operation (SVO) Roadmap





### **Build community of interest and consensus**

- Effort includes building a community, not just technology
  - Participation of industry, academia and the FAA essential to project formulation, execution, commercialization
  - Oshkosh forums, July 21 (public) and 22 (Industry)
  - Kansas City workshop in collaboration with FAA
    - Nominally late October
- Connectivity and partnerships with other ARMD, NASA, DoD, DOT investments, programs

# Questions

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# Backup Material

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# Performance: How Safe is Safe Enough?



- Small, commuter airline record highlights that even current small aircraft can conduct scheduled operations with safety higher than cars



- Note, equivalent safety per mile may not be societally sufficient if new mode is used to travel many more miles
  - Annual or life-time risk given typical exposure might be more appropriate
    - E.g 12.5K miles/per year by car for 80 years = 1,000,000 miles and a 0.63% lifetime risk of fatality



## ➤ Underlying safety-critical technologies enabling SVO 1 & 2 are resilient automation, not non-deterministic machine intelligence

- Human retains overall responsibility for safety of flight, but is **totally relieved** from many low-level tasks and responsibilities that 1) increase training, 2) often bite (e.g. stall awareness)
  - Integrate existing, near-existing technologies to create deterministic **automation as reliable as structure**
  - Machine intelligence introduced, but not for safety-critical tasks; gain experience before critical reliance
  - Possibility of support from off-board personal, for example
    - Pre-flight, loading
    - Dispatcher-like support





## ➤ Underlying safety-critical technologies enabling SVO 1 & 2 are resilient automation, not non-deterministic machine intelligence

- Sub-component failures, rare-normals must not require novel piloting skills, for example
  - Engine-out
  - Ice encounter
  - Loss of GPS
- Automation capable of emergency landing if pilot incapacitated
  - Digital (and/or physical) parachute
  - Much less demanding than full-mission automation due to special handling by other elements of the system (e.g. traffic cleared away) and relaxed cert requirements due to rarity of use (back-up to a rare event, not primary capability)
- Dissimilar strengths and limitations of human and automation increase joint system safety and performance while reducing costs and certification risk



## ➤ **Final convergence of UAS and manned aviation**

- Passenger carrying UAS

## ➤ **Requires fundamental breakthroughs in machine intelligence**

- Time horizon uncertain
- Current reliability of autonomous aircraft maybe 99.9% (in benign weather), but carrying humans as cargo requires 99.9999% or better
  - Full autonomy is estimated to be > 3-4 orders of magnitude more challenging than required for SVO-1 or 2
  - Incremental introduction still needed validate safe operation in real-world, novel situations
    - UAS experience will be useful, but sUAS likely to take advantage of options not appropriate for manned aircraft and larger UAS likely to rely on remote pilots

## ➤ **SVO-3 leverages SVO 1, 2 and of course, advance autonomous vehicle research**

- Ideally, common-core across vehicle classes, applications